Characterization of Shark Fin Collagen Fiber for Species Identification

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Abstract

Sharks are being fished for their fins at an unsustainable rate. Shark finning laws have been enacted in an attempt to reduce the amount of shark finning that occurs, however there currently is no way to identify a shark fin once the skin is removed and only the collagen fibers remain without the use of DNA. This means that there is no way for law enforcement to differentiate those fibers from the fibers of any other species. This differentiation between species of sharks is important since there are different levels of protection for different shark species. A simple, inexpensive method must be created in order for law enforcement in the field to reduce the illegal finning of sharks. The fin samples for this research were collected from various shark fishing tournaments after the obtainment of proper state and federal permits. The samples were documented, measured, and photographed in fresh form, in salted form, and then the fins were measured again after sun drying. The salting process began the dehydration of the shark fin. Then the sun drying process was completed until the fins were rigid and the collagen fibers could be seen through the skin of the fin. The thickness of the fins decreased after sun drying due to the loss of water in the fins; however, the proximal-distal (length) and the caudal-cephalic (width) measurements did not. Observations of the girth of blue sharks and the total length of common threshers were supported by statistical analysis run in GenStat v16.2.11713. Results confirmed the slender body of the blue shark and that female common threshers are larger than male common thresher sharks.

Introduction

Shark finning is the act of cutting off a shark's fins and discarding the body at sea (Verlecar, 2007). It has been estimated that anywhere from 26 million to 73 million sharks are killed each year (Techera, 2012). The shark fins are used to create shark fin soup, which is an Asian delicacy. The shark fin soup is often served at important events and ceremonies as a symbol of respect to the guests. The shark fins are categorized by grade. Grading of the shark fin is based off of what species the fin is from, the fin size, quality of the fin, and the type of fin. The most valuable fins are first grade fins which include the first dorsal fin, the pectoral fins, and the lower lobe of the caudal fin. Some of the highest grade sharks are the blue sharks, mako sharks, hammerhead sharks, and the sandbar shark. Besides the grade of the shark fins, the value of the shark fins also depends on the amount of collagen fibers present. Since shark fin soup is made from the collagen fibers of the fin, the amount of fibers present is proportional to the value of the shark fin (Vannuccini, 1999).

Due to the rise in shark finning, laws have been created to protect the shark populations. The first federal shark fin law is called the Shark Prohibition Act of 2000. The legislation made it illegal to remove the shark fins and dispose of the carcass at sea, and it prevented fishing vessels from having shark fins onboard the vessel without the carcass onboard (GPO, 2000). However, since this law specifically stated that fishing vessels needed to possess the carcass and the fins, other vessels did not have to adhere to this law. This led to the creation of the Shark Conservation Act of 2010 which stated that the fins had to be naturally attached to the shark when landed in United States territorial waters (GPO, 2011). In addition to the federal legislation, nine states have created their own legislation regarding shark fins. These states are California, Illinois, New York, Hawaii, Maryland, Delaware, Oregon, Washington, (The Humane Society, 2013) and Massachusetts (New England Aquarium, 2014). While all of these legislations have the same goal, the consequences that violators face differ between states. For example, violations in New York can carry up to fifteen days in jail and a $100 fine per shark (Humane Society, 2013) while violators in Massachusetts could face up to sixty days in jail, fines up to $1000, and potential loss of their fishing license (Rosen, 2014).

There are some exemptions to these federal laws which can be granted through permitting. One permit that can be obtained is the "National Marine Fisheries Service Highly Migratory Species Management Division Exempted Fishing Permit". This permit will clearly specify what the permit approves such as activities that are allowed to be conducted, who is allowed to conduct the activities, which species are able to be sampled, and reporting requirements. Also, for states that have created their own shark finning laws, state permits need to be obtained stating what activities have been approved.

Besides laws and permits used to protect sharks from finning, other organizations exist to protect shark populations as well. One of these organizations is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES is an international agreement which ensures that international trade will not threaten the survival of a species. While CITES sole focus is not sharks, it does protect certain shark species. CITES categorizes its species into three Appendices based off of the level of protection needed to ensure their survival. Appendix I species includes animals that are threatened near extinction and requires a special permit in order to be traded, an Appendix II species includes species which are threatened with over-exploitation, and an Appendix III species includes animals that are protected in at least one country. Another organization which monitors animals' conservation status is the International Union for

Conservation of Nature (IUCN). The IUCN Red List categorizes species based off of their conservation status. This organization lists species as either least concern, near threatened, vulnerable, endangered, critically endangered, extinct in the wild, and extinct.

Sharks, skates, and rays are classified under Chondrichthyes, a class of cartilaginous fish. This class is broken down into two subclasses known as Elasmobranch and Holocephali in which sharks are grouped under the Elasmobranch group. This group characteristically is known for having multiple reproductive types differing between species and low fecundity rates. High reproductive maturity ages, long gestation periods, and small litter size contribute to the low fecundity levels.

An identifying characteristic of sharks are the number, shape, size, and coloration of their fins. The maximum number of fins a shark will possess is eight, including two pectoral fins, two pelvic fins, dorsal, second dorsal, anal, and caudal fins. The fins are made solely of cartilage fibers and a cartilaginous platelet that runs through the center of the fin. All fins in the sharks are made up of cartilage and collagen fibers. Collagen is a tough, but flexible fiber that is held together and surrounds the cartilaginous platelet. These fibers are often known as fin needles, for they extend from the proximal end to the distal end and tapper as they approach the tip of the fin. In order to distinguish between species of shark, the features of the fins are often utilized. The blue, short-fin mako, and the common thresher are the three shark species in which the fins will be examined for the purpose of this research.

The dorsal side of the short-fin mako, *Isurus oxyrinchus* (Rafinesque, 1810) has a metallic blue coloration while the ventral side has a white coloration. The short-fin mako has eight total fins; the left/right pelvic fins, the left/right pectoral fins, the first/second dorsal fins, the caudal fin, and the anal fin. The caudal fin of the shortfin mako has a unique design which minimizes drag and maximizes thrust allowing for maximum momentum. This allows the short-fin mako to be the fastest shark. A female short-fin mako is ovoviviparous with a gestation period of 15 to 18 months. Their litter size ranges from eight to ten pups. At birth, pups are typically 68 to 70 cm long and they can grow up to 3.2 m long (Passarelli, n.d.). The short-fin mako has a life span of 29 to 32 years, and once they reach maturity, they will typically reproduce every three years. The short-fin mako is listed as vulnerable by the IUCN Red List due to the high value that is placed on their meat and fins which is causing overfishing (Calliet, 2009).

The common thresher shark, *Alopias vulpinus* (Bonnaterre, 1788) has a dark brown to slate-gray coloration. They have six total fins; the left/right pectoral fins, the left/right pelvic fins, the dorsal fin, and the caudal fin. A common thresher shark can be easily identified based off of its long upper lobe of the caudal fin (Jordan, n.d.). A female common thresher shark is ovoviviparous with a typical gestation period of nine months. Mating usually occurs in mid to late summer, which means pups are usually birthed in spring. (Goldman, 2009) Common thresher sharks reproduce annually with litter sizes of two to four pups (Jordan, n.d.). Female common thresher sharks are believed to mature between ages three to nine years old while males are believed to mature between ages three to seven years old. Since these sharks have small litter sizes, they would not be able to quickly recover from over exploitation, which is why they are listed as vulnerable by the IUCN Red List (Goldman, 2009).

The blue shark, *Prionace glauca* (Linnaeus, 1758), is a member of the Elasmobranch subclass that is widely distributed throughout the Atlantic, Pacific, and Indian Oceans. They are currently an abundant species, however due to low fecundity and increased levels of shark finning, the sustainability of the population is in jeopardy. The IUCN Red List of Threatened Species listed them as “Near Threatened” (Stevens, 2009). Morphologically, the blue shark has a long, slender bright blue body and a white underside. Blue sharks have eight fins and five gill slits. Distinctive characteristics of the fins include a larger first dorsal than the second, long and slim pectoral fins, and a caudal fin in which the upper lobe is longer than the lower lobe. This species will live 20 years or more and will begin reproducing when sexually mature. Maximum length is 3.8 meters with pup size ranging from 35 to 44 cm (Carwardine, 2002).

The purpose of this research is to find if there are morphological differences in the collagen fibers of shark species. Law enforcement currently does not have an easy, inexpensive way to look at fibers of fins specifically. Although DNA tests are being developed, these tests are costly for police departments. Simple examinations of fibers using microscopy would be an ideal method to differentiate between fins in fiber form. Without tests to differentiate shark from ray and skate, law enforcement cannot justify that the fins are shark and were illegally fished. Differentiation between species is also necessary, for there are different levels of protection between species of sharks that prosecutors can use to increase punishment for illegal actions, thus demoting illegal shark finning activities. This research will aid law enforcement in reducing illegal fishing through the application of forensic science.

Materials and Methods

Prior to any research being conducted both federal and state permits (where necessary) were obtained (Federal: SHK-EFP-14-19 and State: NYS#1142) Since the federal permit was acquired, the state of Connecticut did not require additional permitting. After permits were obtained, samples were collected from shark fishing tournaments. Tournament locations included New York, Massachusetts, and Rhode Island. A sampling kit composed of knives, Tyvex tags, zip ties, sharpies, garbage bags, alcohol swabs, a tape measure, a field notebook, a camera, and an L-shaped scale.

At the tournaments, the National Oceanographic and Atmospheric Administration (NOAA) group of scientists took measurements on weight, fork length, girth, sex, and when possible, total length. This information was recorded in the field notebook. If given permission by the captain of the boat, full fin samples were taken. Using a serrated blade, cuts were made along the body of the animal.

Once fins were removed from the carcass they were placed into labeled black garbage bags. Bags were placed into coolers and moved into a freezer upon arrival at the University of New Haven (UNH) for preservation purposes.

Documentation of samples was completed at UNH. Initial measurements were taken such as maximum height (proximal-distal) and the length of the base (caudal-cephalic).These measurements and the data collected at the tournament were written into a log book and entered into an electronic database. Scaled photographs were taken of both sides of the fins. Every individual fin was labeled with the sample number, date, and fin type.

Trade of fins occurs in all states of preservation however for the purpose of this project, fins will be observed at a sun dried state. Therefore, after documentation was completed, fins were covered with salt for twenty four hours to aid in the removal of moisture. Before placing the fins in the sun, the excess salt was removed. The fins were then placed into the sun for 2 to 8 weeks until rigid. Once dried, measurements were retaken and the fins were stored in labeled breathable bags.

Results

Collection of samples concluded with 93 total shark samples. The three most abundant were the blue (18 samples), short-fin mako (35 samples), and common thresher shark (19 samples). These three species will be used for statistical comparisons and analysis in future works.

Common thresher, short-fin mako, and blue shark numbers were the most populous due to the regulations and locations of the fishing tournaments. In the northeast Atlantic Ocean, these three species are common. Other species such as porbeagle and tiger sharks are less common in these waters. Protection of other species such as the great white shark helps to prevent them from being fished without the proper permit and are not permitted to be fished for recreational purposes.

Sun drying was completed over a period of two to eight weeks, depending on the size and thickness of the fin. Size and thickness determine how long it takes for the moisture to be removed, for larger fins will take more time. After sun drying, it was observed that coloration of the fins did not change however the exposed baseline (where the fin removal occurred) was a yellow to dark brown color. Change of fiber color is unknown for fibers were not exposed before, nor after sun drying occurred.

Sun drying caused a changed in the elasticity of the fins. Initially fins were flexible, but after sun drying they were stiff and unbendable. Sun drying altered the thickness of the fins, allowing the fibers to be seen through the skin. The fibers ran parallel to each other and parallel to the proximal and distal ends of the fin, as seen in Figure One.

Figure One: Photograph of dried fin and the exposure of fibers through the skin.

Observations of each type of fin showed that the larger the fin, the more fibers there are present. Pectoral fins have needles that run the entire length, which is much more valuable in the black market than the entire length of an anal or pelvic fin. The caudal fins all had more fibers in the lower portion of the fin, the lower lobe, which supports the high value for this ventral lobe of a shark. Results of the sun drying process demonstrated that the fins contain cartilaginous fibers within the fin. The presence of the fibers was found in all types of fins including the caudal, dorsal, pectoral, pelvic, and anal fins.

Statistical Analysis was completed using the program GenStat v16.2.11713. Analysis was completed to distinguish relationships between variants of the study and also to find summary statistics. The first test completed was statistical summaries by sex and by species. The mean and medium of fork length, girth, and total length were all calculated. The mean and medium of fork length for male blue sharks were 230 ± 5.027 cm and 230 cm. No mean and medium were calculated for female blue sharks, for there were no samples collected of this kind. The mean and medium for male short-fin mako sharks are 193.5 ± 6.633 cm and 203.4 cm. For female short-fin mako sharks collected, the mean value was 201.8 ± 4.777 cm and median was 207.3cm. The Common Thresher males have a mean fork length of 195.2 ± 6.068 cm and a median of 202.3 cm. Lastly, the common thresher females have a mean fork length of 210.5 ± 10.96 cm and a median of 201cm. Statistical analysis of the girth restricted by sex and species of shark demonstrated that for the samples collected, the common thresher male sharks are the largest mean girth (108.3± 3.546 cm). The species with the lowest mean girth (85.12 ± 2.272 cm) was the male blue shark. The total length was recorded mostly for thresher sharks and not the two other species. Comparing the male and female thresher sharks' total length to each other, the female has a larger mean total length, 391.5 ± 26.06 cm, while the male mean total length is 321.4± 36.04 cm.

An analysis of variance between proximal-distal length of the dorsal and sex differentiation was ran using blocking of common name. This test determined that there is a p value less than 0.001 for the differences between the species, however the p value was 0.423 for the differences between sex, which is not statistically significant.

Summary statistics and analysis of variance concluded a direct relationship between the pectoral proximal distal length and the girth (cm). The analysis produced a percentage variance (R^2) of 79.1 and a standard error of 4.55. The total degrees of freedom were 133 and the p value was <0.001. The blue shark was ran as the reference and the p-values for the short fin mako and thresher shark were found to be <0.001 (t(128)= 1.95) and 0.053 (t(128)= 3.50), respectively. Therefore the overall relationship between pectoral proximal-distal length and girth is statistically significant. At the individual level, in comparison to the blue shark, the short-fin mako shark is statistically significant however the common thresher is not.

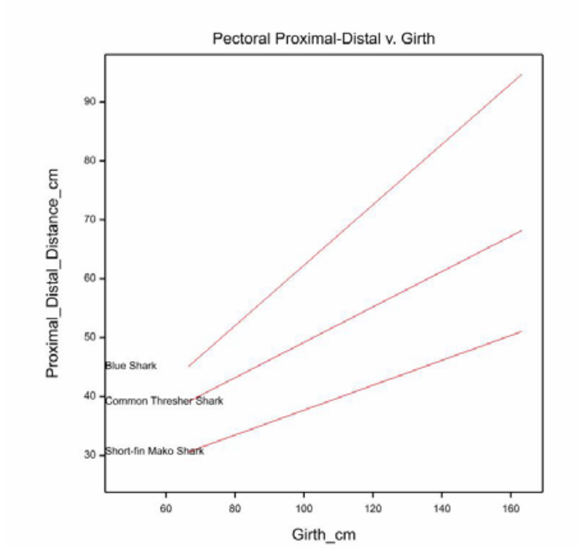

Figure Two: Relationship between pectoral proximal-distal lengths to the girth of the fish, by species. (D.f.=133) Overall R^2=79.1, p,0.001.

Statistical analysis of the relationship between pectoral proximal-distal length and fork length were compared. The overall R^2 value is 90.6 and the p-value is <0.001. In reference to the blue shark, the common thresher was statistically significant with a p-value of 0.002 (t(122)=3.15). Also in reference to the blue shark, the short-fin mako had a p-value of 0.010 (t(122)=2.62), which is also statistically significant. Therefore the relationship between pectoral proximal-distal length and fork-length are significant at a <0.001 level.

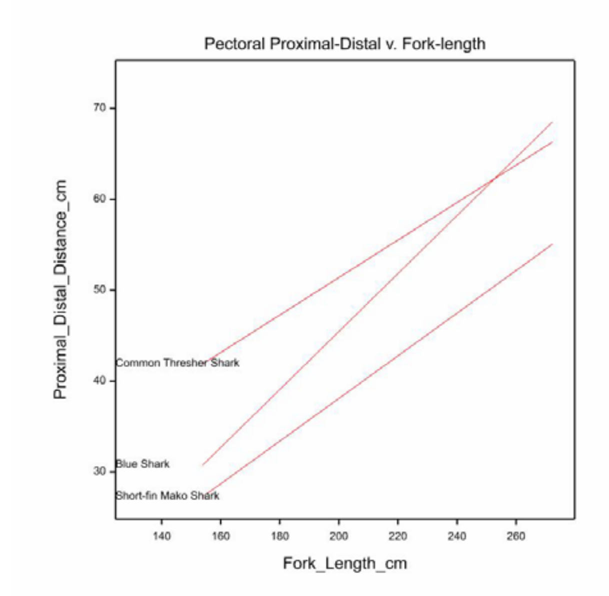

Figure Three: Relationship between fork length and proximal-distal length of the pectoral fins, grouped by species. Overall R^2=90.6, p< 0.001.

The relationship of fork length and girth show an overall statistical significance between them. The R^2 value is 68.6 and the overall p-value is less than 0.001. The common thresher is not significant in comparison to the blue shark with a p-value of 0.755 (t(118)=0.31). Also in comparison to the blue shark, the short fin mako shark p-value is 0.013 (t(118)=2.51), which is statistically significant.

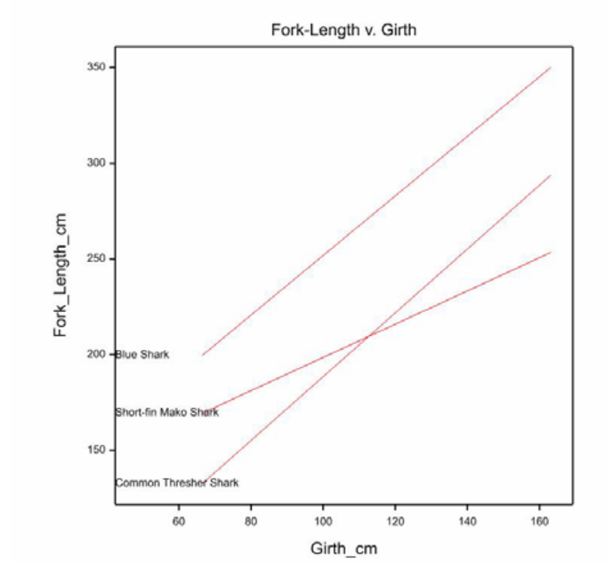

Figure four: Relationship of fork-length v. girth, grouped by species. Overall R^2=68.6, p<0.001.

Discussion

Statistical analysis showed correlations between girth and the species of shark. It was determined that the blue shark has the smallest mean girth of the three species. This can be attributed to the long, slender body of the blue shark and supports this observation that was made. The girth of the short-fin mako and thresher are larger than the blue shark, for they have a body shape that has a slight concavity on their underside, with the concavity increasing with weight.

Analysis also determined that the proximal-distal length of the dorsal fin had no statistical significance when compared to the sex of the animal. Therefore, within the common thresher, blue, and short-fin mako shark, the dorsal fin length does not vary by species. This is contradictory to the previous research studied. In most species of shark, including the three being studied here, females tend to be larger in size. Since fin size is correlated with body size, the females should have a larger dorsal than the males. Perhaps the subjects being studied in this experiment were skewed in that the females were of a younger age and thus a smaller size than if they were aged.

In the future, the skin of the shark fins will be removed from the fins allowing the collagen fibers to be exposed. Microscopic examination of fibers will be completed in an attempt to differentiate the different shark species from one another. This entire process will then be performed with skate and ray in an attempt to differentiate these closely related species from each other. The shark fins will also be examined after various heat treatments to determine the effect that heating has on the fibers, as done in shark fin soup.

Conclusion

This study took samples of shark fin and converted them to dried shark fin, a form that is commonly found in the black market trade. The conversion of fins showed a change in thickness, which supports that dehydration of the fins occurred. Within the samples themselves, it was determined that for the sample size of this experiment, there was no statistical significance between the dorsal proximal-distal length and the sex of the animal by species. Analysis also determined that the male blue shark has the smallest girth and that the female common thresher has the longest total length in centimeters. These results contribute to the knowledge of the species themselves and contribute to the future analysis of the fins. This study will be continued and removal of the skin and rehydration will occur in order to expose the fibers. Fibers will be looked at using simple microscopy techniques to be used as a future forensic science technique for law enforcement.

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Biographies

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Jennifer Corwin is originally from Rochester New York and attended Spencerport High School. Jennifer is a senior at UNH and is graduating in May 2015 with a double major in Forensic Science and Biology and a double minor in Chemistry and Mathematics. Following graduation, Jennifer plans to have a career in either a forensic or biology laboratory. She plans to continue her studies and attend graduate school in a few years. Jennifer is involved in Alpha Lambda Delta Honor Society and Forensic Science and Chemistry Club.

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Jamie Wakeman is currently a senior at the University of New Haven. She is graduating in May 2015 with a double major in Forensic Science and Pre-Med as well as a minor in chemistry. Jamie is from South Salem, NY where she attended John Jay High School. After graduation from UNH, Jamie is planning on working in a biology laboratory with hopes of continuing her education in several years.

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